Sonar Detection and Classification of Buried or Partially Buried Objects In Cluttered Environment Using UUVs

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Grant Number #:N00014-96-I-5023
http://www.oe.fau.edu/CHIRP/CHIRP.html

LONG TERM GOALS

The long term goal of this program is to develop acoustic reflection methods and acoustic processing techniques for detecting, imaging and classifying objects buried in the seabed such that methods can be eventually implemented on UUVs.

TECHOLOGICAL OBJECTIVES

- To generate databases of buried target strengths, volume and surface scattering coefficients and sediment acoustic properties over a wide frequency range that can be used for sonar prediction modeling
- To determine the best image processing and visualization techniques for buried object imaging
- Develop a prototype sonar with nearfield focusing capability for testing signal processing and imaging techniques
- To develop sonar models that predict the SNR of targets for various array geometries, sediment types, frequency bands, etc
- To establish the feasibility of using boundary (evanescent compressional waves) for long range detection of buried objects outside the critical angle.
- Develop acoustic models of sound interacting with the seafloor to provide a theoretical basis for signal processing techniques and predicting the detection of buried objects

APPROACH

In order to develop a UUV sonar for detecting and imaging buried mines, the phenomenon of volume and surface scattering from the sediments, fluid / porous solid boundary-interacting acoustics, and the interaction of sound with elastic objects contained with a porous solid must be understood so that the signal levels and interference can be accurately calculated when estimating sonar performance of a particular design. An experimental approach is being taken to determine those acoustic processes. Two sonars have been constructed to measure the effects of sound interacting with the seabed and to measure the characteristics of target echoes. The sonars provide a direct measurement of the target echo strength and acoustic scattering levels as a function of frequency. The first sonar used a 3m wide by 1m long towed vehicle containing a 0.75 m long line transmitter and 16 line hydrophones covering an aperture of 0.75 by 3 meters. A 16 channel sonar processor was used to collect the 16 channels of reflection data. The data was sent to a topside processor via a 100 Base T link for display and storage

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **1998**	2. REPORT TYPE	3. DATES COVERED **00-00-1998 to 00-00-1998**
4. TITLE AND SUBTITLE **Sonar Detection and Classification of Buried or Partially Buried Objects in Cluttered Environment Using UUVs**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Florida Atlantic University,Department of Ocean Engineering,Boca Raton,FL,33431**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES **See also ADM002252.**		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

and merging with underwater video. The data from the first sonar, covering the frequency range of 1.5 to 10 kHz, was used for testing across track focusing.

CEROS (DARPA) funded the hardware development for a second sonar that has a steerable transmit beam and allows across track and along track focusing. This sonar is much more compact and has a frequency range of 4-30 kHz. The 1 by 1 meter the towed vehicle contains a 6 element transmitting array and a 8 hydrophone arrays with 4 hydrophones each. The sonar processor on the fish steers the transmit beam and acquires 32 channels of reflection data which is sent to the topside processor via 100 Base T for display and storage. The two sonars are designed to provide integrated video and acoustic data sets for measuring the impulse response of buried targets and the scattering interference from sediments in the vicinity of the targets. The compact sonar steers the transmission beam forward thereby substantially reducing the high scattering levels from the sediment water interface at near normal incidence that make it difficult to detect objects near that interface. Dr. Schock and Jim Wulf supervise the research which is conducted by graduate and undergraduate students. Jim Wulf is a retired engineer from IBM who designed and tested the electronic components of the sonar processors. Arnaud Tellier, who is scheduled to complete his Master's of Science thesis by December 1998, developed a simulation that predicts the images generated by the 16 channel beamformer for spherical elastic targets in a fluid. Eric Bauer, an undergraduate students assists in preparing and conducting experiments.

WORK COMPLETED

During the past year, I completed the development of the compact (1m x 1m) 32 channel sonar that will allow along track and across track beam steering. Sea testing is scheduled for November 1998. Underwater video was integrated into the larger 1m x 3m sonar vehicle to allow better correlation between subsurface echoes and target locations. Volume and surface visualization techniques have been developed and tested on synthetic data. The marching cubes method was selected as the surface rendering technique. Simulations of the nearfield beamformer for the case of imaging elastic spherical targets in a fluid were performed to show that double echoes can be expected to be seen in images and that the spacing of the second echo depends on the shear modulus of the elastic material.

RESULTS

It is common to see double echoes in the images of buried objects. Simulations of the beamformer processing echoes from elastic spheres in a fluid show very clearly that double echoes can be expected from buried objects and that the spacing of the second echo depends on material properties as well as the dimensions of the targets. The simulations also show that the strongest echo will arrive from the location of the closest surface that is normal to the sonar focusing axis. Generating an image of the outline of the target is not possible; for the most part the echoes originate from the closest normal surface to the sonar.

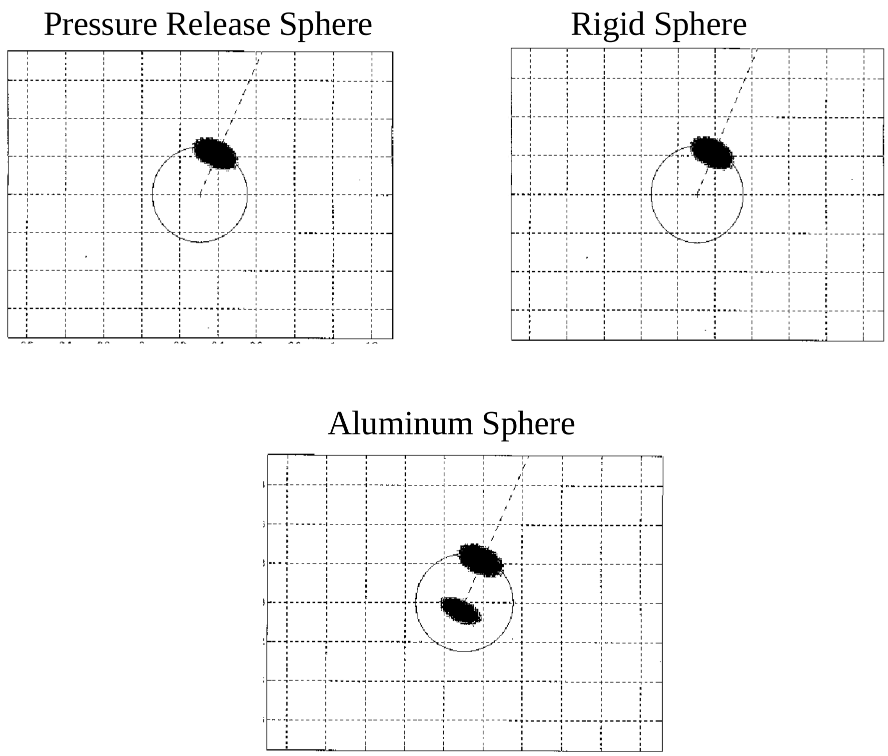

Figure 1 Simulated output of nearfield focusing beamformer showing that double echoes can be expected to be seen for elastic targets and that the second echo does not correspond to the far side of the target surface. The spacing of the second echo depends on the shear modulus in addition to the target dimension and shape.

IMPACT/APPLICATIONS

The imaging sonars developed under this program can be used for finding buried mines and ordnance. The second compact sonar, developed by cost sharing between this grant and a CEROS/DARPA contract, can be incorporated into UUVs. Real time target detection research needs to be completed before the UUV implementation can be considered. Scattering and target strength measurements can be used to predict sonar performance and to aid in the development of other buried object sonars by the Navy.

TRANSITIONS

The general purpose sonar technology has been transitioned to industry, academia and the Navy. The general purpose sonar was licensed to Edgetech. The technology is contained in sonars used by Naval Facilities Engineering Service Center and Woods Hole Oceanographic Institute who will be using the sonars to measure the impulse response of the seabed over the range of 1 to 14 kHz for the purposes of classifying ocean sediments.

The focusing technology was modified for a DARPA sponsored program, administered by CEROS, for the development of a system for detecting and classifying buried ordnance. The system has the additional capability of fore/aft beamsteering in addition to across track beamsteering and is much more compact so it is more suitable for UUV applications.. The sonar transmits over the range of 4 to 30 kHz.

RELATED PROJECTS

CEROS/DARPA contract "Development of a 3-D, Forward/Aft Sweeping, High Resolution Buried Object Imaging System"

PUBLICATIONS

1. "Schock, S.G., :"Buried object scanning sonar" Oceanology International, Brighton, March 1998.